

# Reduction of energy use by efficient cooling of strawberries:

from model calculation to implementation in a commercial greenhouse

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## Problem of strawberry cultivation: history

- Start of crop cycle begin of August
- Enough assimilates (light) for
- Production and flower bud development

But:

- A premature harvest with low production
- Growers postpone start to second half of august
- Extra energy cost



How to create a cooler night climate?



A grower had already installed coolers in his greenhouse

## Result of cooling

Was quite poor:

- It was difficult to reduce greenhouse air temperature during night

### How to improve?

- Expert panel with goal:
  - Create hypothesis growing strawberries
  - How to use and improve efficiency of cooling
  - No restrictions to crop production and quality
  - Reduction of energy consumption from  $20 \text{ m}^3/\text{m}^2$  to  $14 \text{ m}^3/\text{m}^2$



## Strawberry expert panel (1)



Series of discussions with a group of experts: strawberry, technicians etc.

## Strawberry expert panel (2)

Result of discussion:

**Hypothesis: Start in begin of August**

- Produces enough assimilates for production and an early start of bud development
- Cooling (reducing night temperature Aug-Sept) will spread production and increase fruit weight
- Synchronize harvest and flower bud development for spring crop cycle results in energy saving
- Create light- and temperature sum nearby “idea

According:  $13.4 + 0.2 \text{ }^{\circ}\text{C per } 100 \text{ J/cm}^2$



## Strawberry expert panel (3)

### How to reduce energy use?

- Mechanical cooling will increase energy use
  - Other cooling methods misting, shading
- In practice severe use of minimum pipe temperatures for humidity control → air movement around the plant
- Misting as cooling method during night?
  - Too high humidity
  - A high humidity cooling stops
  - Natural ventilation (temperature effect) will decrease
- With model calculation optimize the experimental setup

## Model calculations (1)

### Course of low cooling result:

heat capacity of the greenhouse (soil)

- Model calculations showed an increase of cooling result when floor was insulated
- Optimization for costs (is insulation rate)
- Permanent? → movable or non movable
- Different effect on greenhouse climate (year around)

## Model calculations (2)

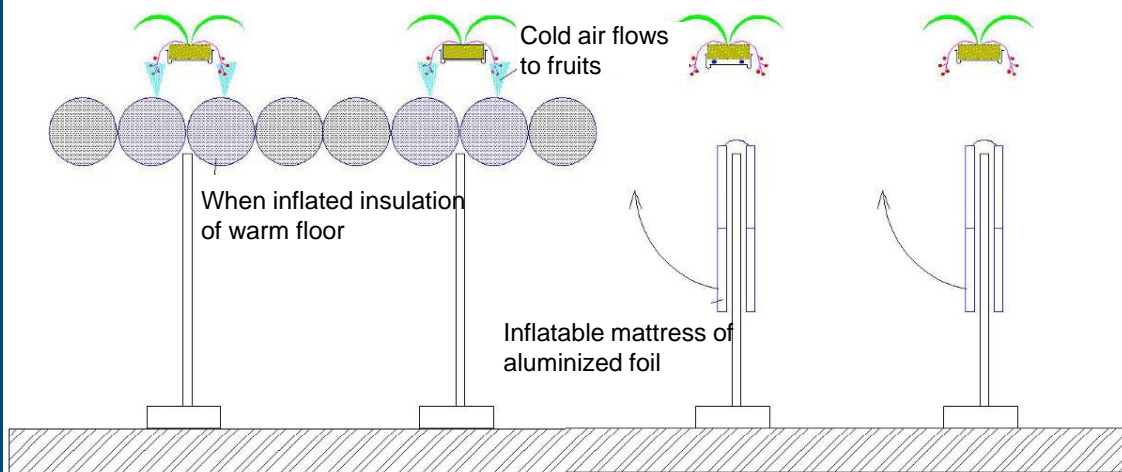
Which solutions are feasible?

- Sustainable
- Easy to use
- Withstand greenhouse environment



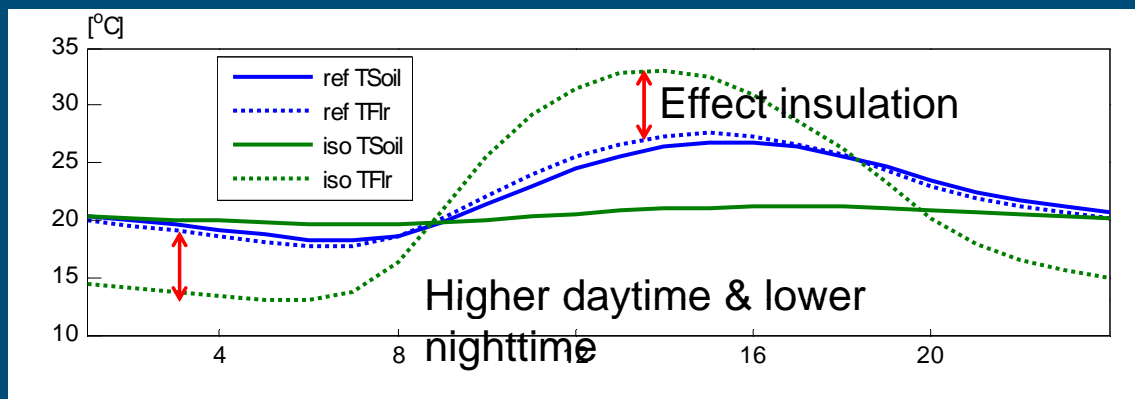
## Model calculations (3)

For climate and energy use movable insulation is best option →  
solution



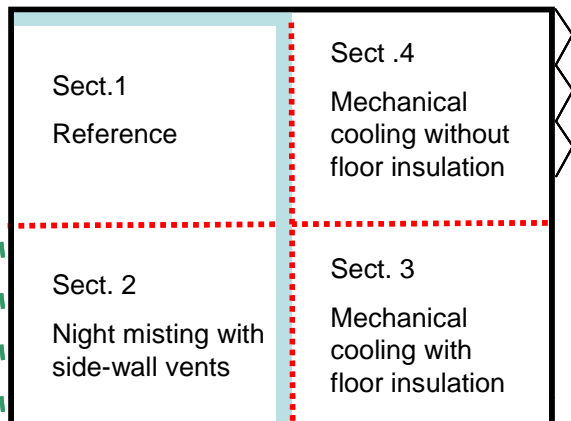
## Model calculations (4)

- Finally: permanent EPS (extruded polystyrene) plates 40 mm thick
- Energy balance of greenhouse changes
- Effect on soil and floor temperature → air temperature
- Average floor and soil temperature for reference and isolated floor from August 10 – September 10<sup>th</sup>



## Setup of experiment (3 treatments)

- | Location of side wall fans
- Concrete walk way
- Vertical screens for segmentation



Misting  
300 ml/m<sup>2</sup>/h

Vertical fans  
one per 220 m<sup>2</sup>



## Investments

- Local differences
- Shown numbers are a direction for Dutch situation
  - Misting 6 €/m<sup>2</sup>
  - Vertical fans 3 €/m<sup>2</sup>
  - Mechanical cooling 20 €/m<sup>2</sup>
  - Side wall fans 2 €/m<sup>2</sup>
  - Insulation 1 €/cm/m<sup>2</sup> (4 cm)

## Setup of experiment



Side wall fans capacity 8000 m<sup>3</sup>/h each

- inside 15 °C, 90%
- outside 20 °C, 50%

Cool capacity rather poor → 30 W/m<sup>2</sup>

- One unit per 200 m<sup>2</sup>
- Coolers max capacity 200 W/m<sup>2</sup>
- With & without distribution ducts



## Experiment

Plants (CV Elsanta) were planted August 10 and 11<sup>th</sup>

Crop cycle divided in three periods:

- August 10 - January 5<sup>th</sup> and 10<sup>th</sup>
- 3 – 4 weeks cold
- January 28<sup>th</sup> – June 13<sup>th</sup>
- Autumn
  - first harvest September 22<sup>nd</sup> – 28<sup>th</sup>
  - Last harvest December 15<sup>th</sup> – 22<sup>nd</sup>
- Spring
  - Harvest April 5<sup>th</sup> – June 13<sup>th</sup>

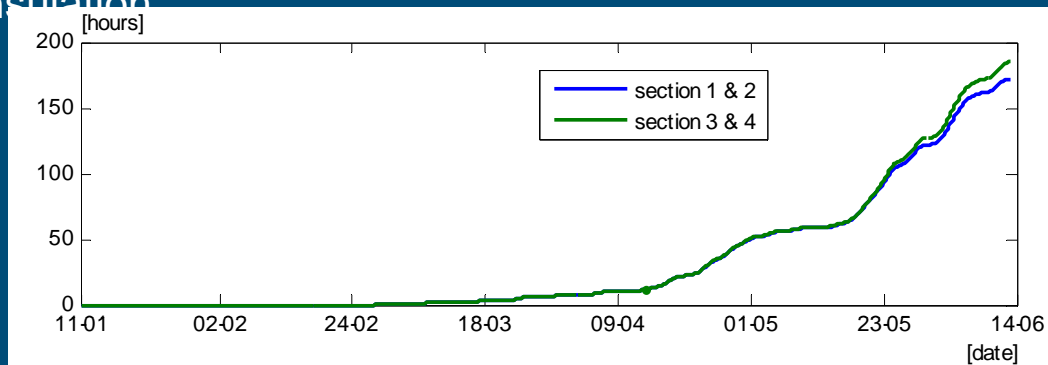
## Use of systems: Autumn

- Only 4 % of run time of side wall fans misting could operate  
→ cooling capacity limited
- Extensive use of misting during day time (Aug. – mid. Oct.)
- Coolers only 25 days used

| Section | misting                   |                             | coolers<br>[h] | Side wall fans<br>[h] |
|---------|---------------------------|-----------------------------|----------------|-----------------------|
|         | Cum. Puls time day<br>[h] | Cum. Puls time night<br>[h] |                |                       |
| 1       | 134                       |                             |                |                       |
| 2       | 134                       | 11                          |                | 257                   |
| 3       | 141                       |                             | 180            |                       |
| 4       | 141                       |                             | 180            |                       |

## Use of systems: Spring

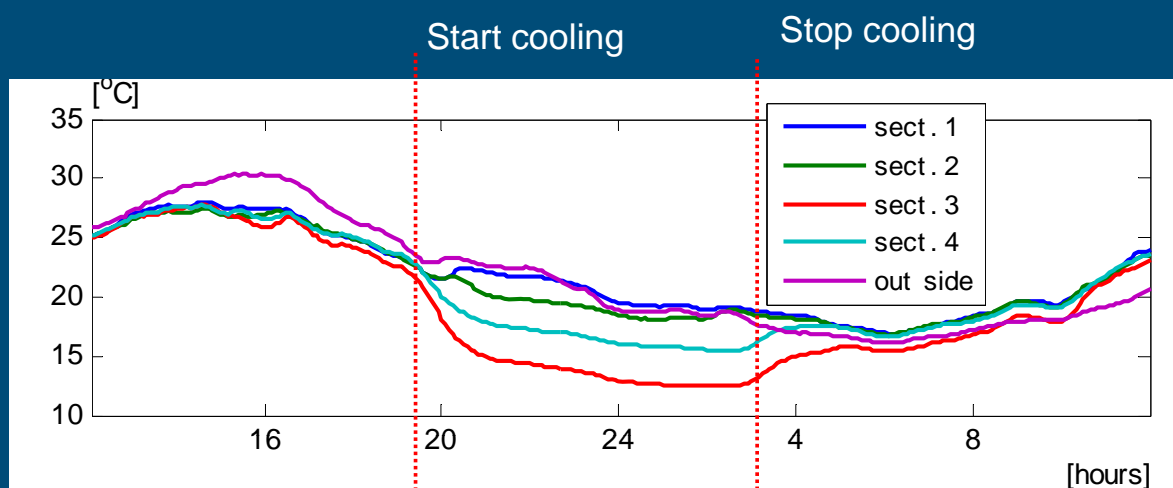
- Side wall fans & misting not used
  - Mechanical coolers not used
  - Extensive use of misting during day time (April – June)
  - Difference in misting is mainly a side effect of floor insulation
- No effect expected on climate by experiment except floor insulation



Cumulated pulse time of misting system in spring

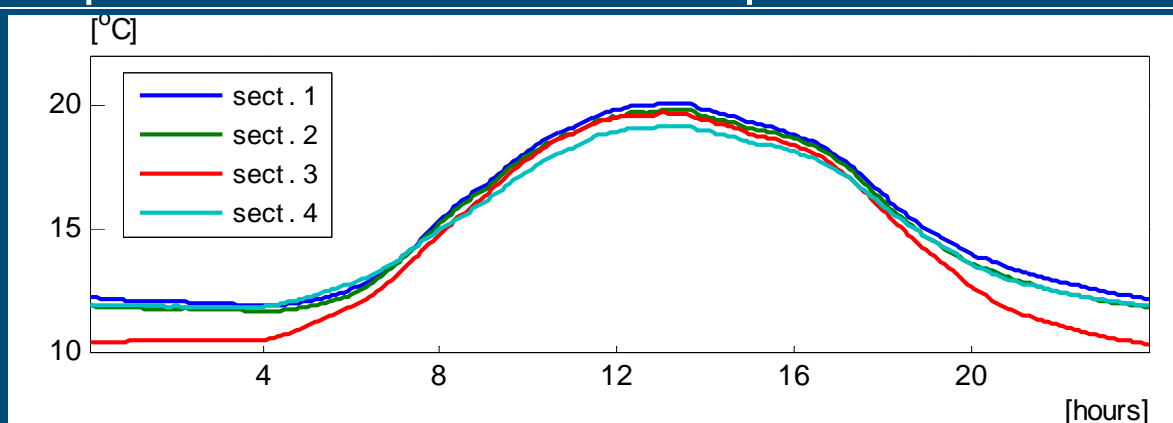
## Experiment: effect of cooling on temperature

- During daytime about 3 °C below outside air temperature
- In night sections 2, 3 and 4 are in average 1.2, 6.7 and 3.7°C lower than section 1 (reference).



August 24<sup>th</sup> 12:00 till 25<sup>th</sup> 12:00

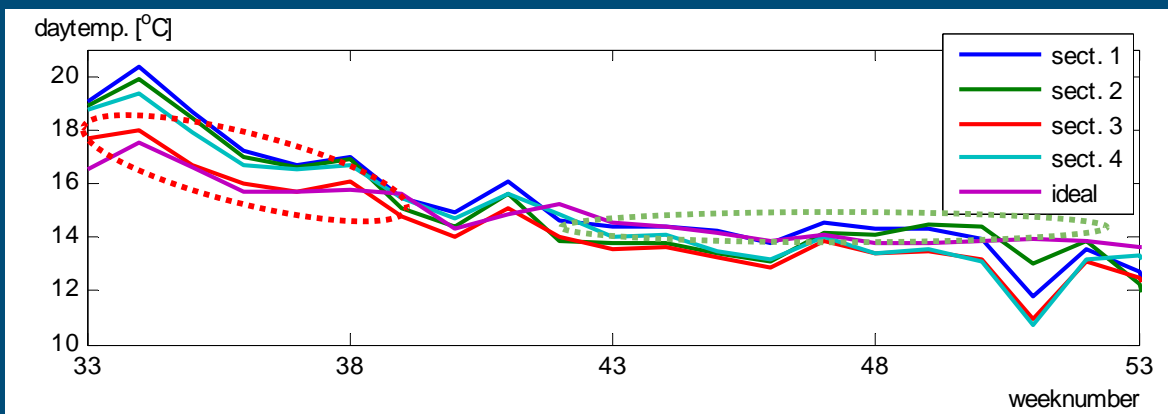
## Experiment: effect on air temperature



Average twenty-four hours temperature course August – December

- Insulation decrease night temperature by 1.5 °C
- Daytime effect in section 3 is result of experimental set-up
- Section 3 more humid (RH)

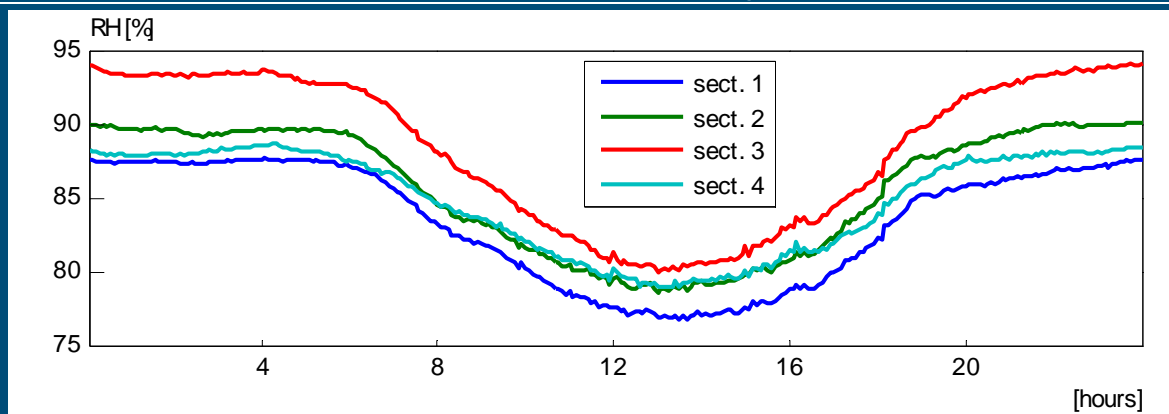
## Experiment: effect on air temperature



Average week temperature

- Week 33 – 40 section 3 about as ideal
- Week 40 – 53 section 1 about ideal rest to cold

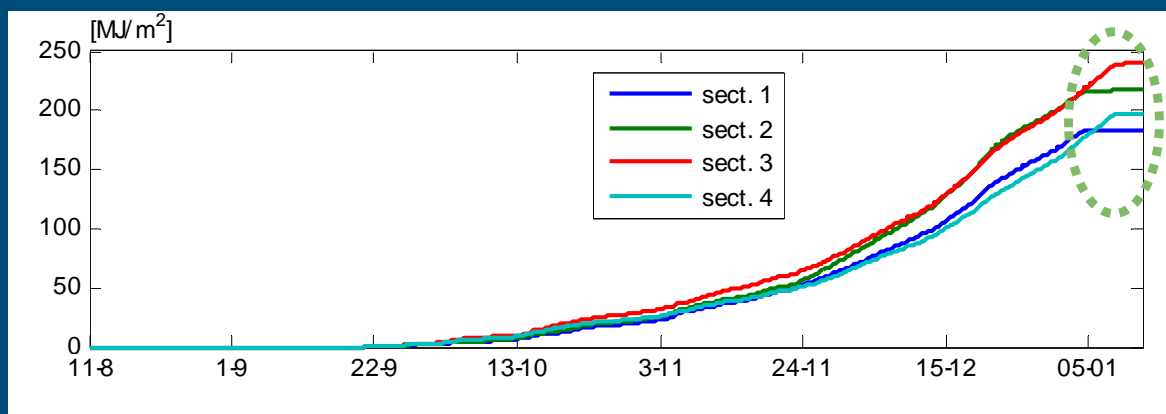
## Experiment: effect on humidity



Average RH during day between August 11<sup>th</sup> and January 5<sup>th</sup>

- During night because of low temperatures higher humidity

## Experiment: energy use autumn



Cumulated energy use in autumn

- Differences between section 1 & 4 and 2 & 3 are small
- Continuation of heating in section 3 and 4 for 6 days cost about 25 MJ/m<sup>2</sup>

1m<sup>3</sup> natural gas is 31.65 MJ

## Experiment: effect on climate & energy

- Autumn section 3 lowest in degrees hours
- Spring section 2 and 3 lowest but differences smaller
- In spring as expected small differences in energy use
- Overall energy use section 3 highest
- Difference in cooling energy is air temperature difference

| section | Degrees hours [ $^{\circ}\text{C}$ ] |        |        | Energy use [ $\text{MJ}/\text{m}^2$ ] |        |       |         |        |       |
|---------|--------------------------------------|--------|--------|---------------------------------------|--------|-------|---------|--------|-------|
|         | 08/10 –<br>09/11                     | Autumn | Spring | cooling                               |        |       | heating |        |       |
|         |                                      |        |        | Autmn                                 | Spring | total | Autumn  | Spring | total |
| 1       | 11534                                | 38381  | 36138  |                                       |        |       | 184     | 210    | 394   |
| 2       | 11342                                | 37433  | 34238  |                                       |        |       | 218     | 220    | 438   |
| 3       | 10224                                | 35328  | 34332  | 34                                    | –      | 34    | 240     | 220    | 460   |
| 4       | 11082                                | 37185  | 35581  | 43                                    | –      | 43    | 197     | 216    | 413   |

## Results: Crop

- Over whole crop cycle (Aug – May) no significant differences in
  - Crop growth
  - Yield
  - Quality
  - Average fruit weight.

| section | Production [kg/m <sup>2</sup> ] |        |       |
|---------|---------------------------------|--------|-------|
|         | Aut-<br>umn                     | spring | total |
| 1       | 5.2                             | 9.3    | 14.5  |
| 2       | 5.4                             | 9.6    | 15.0  |
| 3       | 5.4                             | 9.2    | 14.6  |
| 4       | 5.4                             | 9.6    | 14.9  |

## Results: Crop

- During active cooling in cooled sections
  - Plant load lower
  - Average fruit weight higher
  - Production of fruits lower
  
- Cooling was realized according to plan but we did not not succeeded to spread the harvest.

## Conclusions (1)

- Mechanical cooling in combination with floor insulation can reduce night temperature.
- Mechanical cooling increases energy use
  - Where is the cold water produced? → not taken into account in shown numbers
- Planting date in sections with mechanical cooling was about a week to late.

## Conclusions (2)

- Misting has more effect on climate than mechanical cooling.
  - Reduces even at day time greenhouse air temperature
  - It will increase humidity (prevents extreme low humidity with young plants)
  
- Use of cooling systems was limited (in time)
  - Expensive investment

## Conclusions (3)

- Energy use by early start in august in combination with use of vertical fans drops from around 20 m<sup>3</sup>/m<sup>2</sup> (common practice) to about 14 (season 2009-2010)
  - Main energy saving is result of reduction of use of minimum pipe
  - On time start 2 - 2.5 m<sup>3</sup>/m<sup>2</sup>
- Small increase of energy use by floor insulation

# Questions?

